APPENDIX E: SEDIMENT TRANSPORT MODELING USING EASI MODEL

The surface based bedload equation of Parker (1990a) was developed for wide rectangular channels for which channel geometry can be expressed as a channel width. Details of the surface-based bedload equation of Parker can be found in the original references (Parker 1990a, b). Here only the most essential part of the Parker equation is presented.

The surface based bedload equation of Parker (1990a) for a wide rectangular channel is as follows,

$$\frac{RgQ_G p_i}{Bu_*^3} = \alpha\, F_i\, G\!\left(\omega \phi_{sgo}\left(\overline{D_i}/D_{sg}\right)^{-\beta}\right)$$

(1)

where R denotes the submerged specific gravity of gravel; g denotes the acceleration of gravity; Q_G denotes volumetric bedload transport rate; B denotes channel width; u_* denotes shear velocity; $\overline{D_i}$ denotes the mean grain size of the i-th subrange; p_i denotes the volumetric fraction of the i-th subrange in bedload; F_i denotes the volumetric fraction of the i-th subrange in the surface layer; D_{sg} denotes geometric mean grain size of the surface layer; ϕ_{sgo} is normalized Shields stress; G is a function of the normalized Shields stress ϕ_{sgo} and the arithmetic standard deviation of the surface layer. Coefficients α and β are given as

$$\alpha = 0.00218 \;;\quad \beta = 0.0951$$

(2a,b)

Grain size is described both in diameter and in ψ-scale (Parker 1990b), which is the negative of the ϕ-scale,

$$\psi_i = -\phi_i = \ell og_2\left(D_i\right)$$

(3)

The grain size is divided into N subgroups bounded by N+1 grain sizes ψ_1 (D_1) to ψ_{N+1} (D_{N+1}). The mean grain size of the i-th subrange is then given as

$$\overline{\psi_i} = \frac{\psi_i + \psi_{i+1}}{2}\,,\quad \overline{D_i} = \sqrt{D_i D_{i+1}}$$

(4a,b)

The surface layer mean grain size $\overline{\psi_s}$ and standard deviation $\sigma_{s\psi}$ are as follows,

$$\overline{\psi_s} = \sum_{i=1}^{N} \overline{\psi_i} F_i\,,\quad \sigma_{s\psi}^2 = \sum \left(\overline{\psi_i} - \overline{\psi_s}\right)^2 F_i$$

(5a,b)

and the geometric mean grain size is given as

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$$D_{sg} = 2^{\overline{\psi_s}}$$

(5c)

Note that only particles too coarse to be transported in suspension are included in the calculation. Parker suggested that the finest grain size (D_1) be set as 2 mm (Parker 1990a,b).

Parameter ω is a function of the normalized Shields stress ϕ_{sgo},

$$\omega = 1 + \frac{\sigma_0}{\sigma_{s\psi}}(\omega_0 - 1)$$

(6)

where σ_0 and ω_0 are functions of ϕ_{sgo} given in Figure 1 (Parker 1990a). Tabulated values of σ_0 and ω_0 are also given in Parker 1990b.
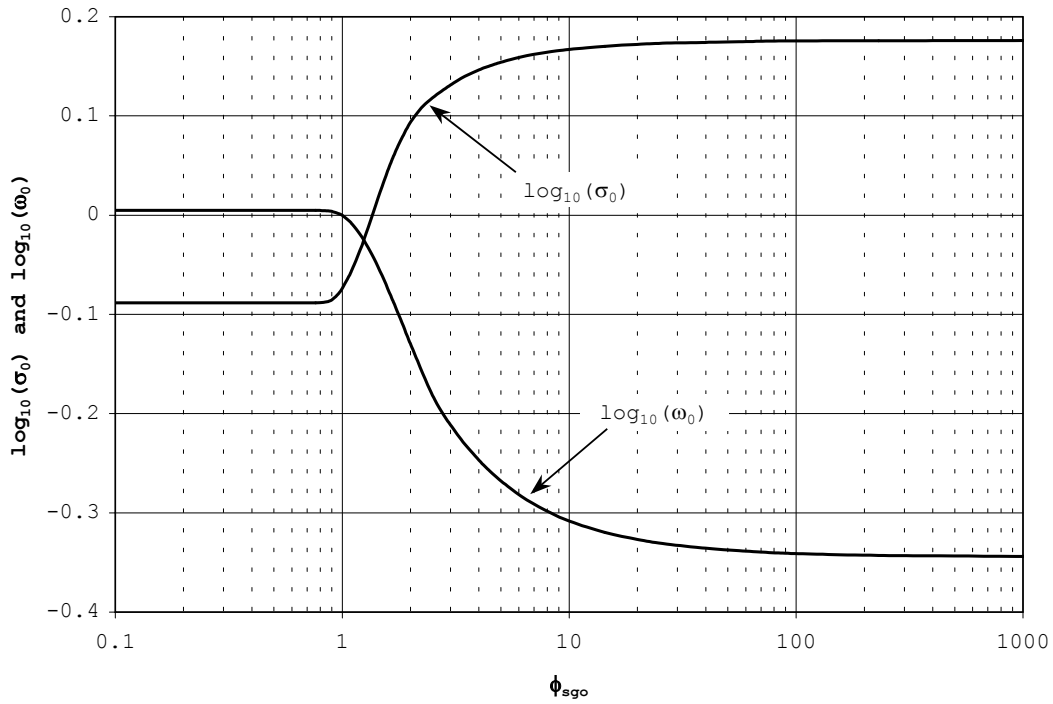
Figure E1. Parameters σ_0 and ω_0 as functions of ϕ_{sgo} in Parker equation.

The normalized Shields stress ϕ_{sgo} is acquired by dividing the surface based Shields stress τ^*_{sg} by a reference stress τ^*_{rsgo},

$$\phi_{sgo} = \frac{\tau^*_{sg}}{\tau^*_{rsgo}}$$

(7)

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where the reference Shields stress τ^*_{rsgo} is given by Parker (1990a) as 0.0386. The surface-based Shields stress τ^*_{sg} is defined as

$$\tau^*_{sg} = \frac{u_*^2}{RgD_{sg}}$$

(8)

Shear velocity u^* is assumed to be the Keulegan resistance relation,

$$\frac{u}{u_*} = 2.5\ell n\left(11\frac{h}{k_s}\right)$$

(9)

in which u denotes flow velocity; h denotes water depth and k_s denotes roughness height. Roughness height is defined slightly differently from the original work of Parker (1990a,b) for simplicity,

$$k_s = 2D_{sg}\sigma_{sg}^{1.28}$$

(10)

where σ_{sg} denotes surface layer geometric standard deviation,

$$\sigma_{sg} = 2^{\sigma_{s\psi}}$$

(11)

Note that the roughness height given by Equation (10) is an approximation of the original value given by Parker (1990a,b), in which the roughness height was defined as twice of surface layer D_{90}.

In case of a normal flow, shear velocity u^* can be expressed as

$$u^* = \sqrt{ghS}$$

(12)

in which S is channel bed slope.

Function G is given by Parker (1990a,b) as

$$G(\phi) = \begin{cases} 5474\left(1-\dfrac{0.853}{\phi}\right)^{4.5} & \phi > 1.59 \\ \exp\left[14.2(\phi-1)-9.28(\phi-1)^2\right] & 1 \le \phi \le 1.59 \\ \phi^{14.2} & \phi < 1 \end{cases}$$

(13)

where ϕ is a dummy variable to be replaced by $\omega\phi_{sgo}\left(\overline{D_i}/D_{sg}\right)^{-\beta}$ in equation 14.

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In case of an arbitrary cross section, the surface-based bedload equation of Parker (Equation 1) and the Keulegan resistance relation (Equation 9) are modified as follows,

$$\frac{RQ_G p_i}{ASu_*} = \alpha\, F_i\, G\!\left(\omega \phi_{sgo} \left(\overline{D_i} / D_{sg}\right)^{-\beta}\right)$$

(14)

$$\frac{u}{u_*} = 2.5\,\ell n\!\left(11\frac{R_h}{k_s}\right)$$

(15)

where A denotes flow area; R_h denotes hydraulic radius of the flow,

$$R_h = \frac{A}{P}$$

(16)

and P denotes the wet perimeter of the channel.

References

Parker, G. 1990a. Surface-based bedload transport relation for gravel rivers. *Journal of Hydraulic Research*, IAHR, 28(4), 417-436.

Parker, G. 1990b. The "ACRONYM" series of PASCAL programs for computing bedload transport in gravel rivers. External Memorandum No. M-220, St. Anthony Falls Laboratory, University of Minnesota, Minneapolis, MN, February, 123p.

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